Enhancing EEG-Based Cognitive State Classification through Graph Neural Networks (GNNs)

TECHNISCHE UNIVERSITÄT DARMSTADT

Proposal for a Master's Thesis Topic

Electroencephalography (EEG) is essential for analyzing brain activity in applications such as emotion recognition, mental state monitoring, and human-computer interaction. Traditional EEG-based classification methods typically focus on individual channel features, overlooking the functional connections between brain regions, which are critical for understanding cognitive and emotional processes. In this study, we propose employing Graph Neural Networks (GNNs) to capture both node-level features (from individual EEG channels) and edge-level features (representing inter-channel connectivity). Our approach involves two strategies: first, inferring edge features from node data during GNN training, and second, explicitly labeling edges using functional connectivity metrics like coherence and correlation. Using these methods on the NMED-T dataset, we aim to classify EEG recordings into three enjoyment levels —low, moderate, and high—through a more comprehensive representation of brain activity.

The main work packages include:

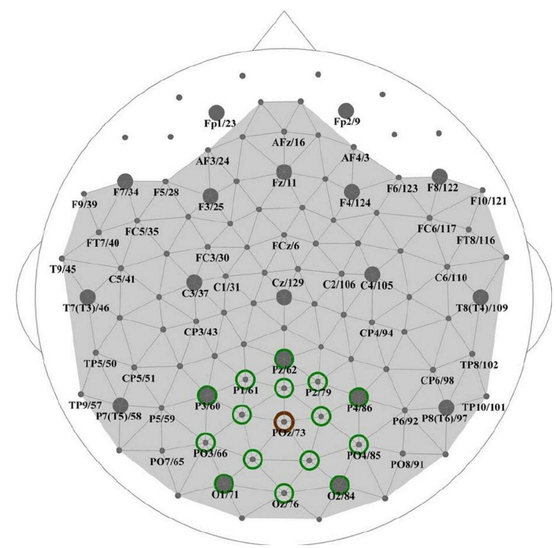
1. **Literature Review:** Examine existing studies on EEG-based emotion classification, GNNs, and edge labeling techniques, highlighting their effectiveness in enhancing classification tasks.
2. **EEG Graph Representation:** Model EEG data as a graph, with nodes representing electrodes that capture localized information, and edges representing functional connections between electrodes.
3. **Feature Engineering:** Extract node features like Power Spectral Density (PSD) and Differential Entropy (DE). For edges, either infer them from node data during training (Approach 1) or explicitly assign edge labels based on functional connectivity metrics like coherence, correlation, or phase-locking values (PLV) (Approach 2), to capture inter-regional brain relationships.
4. **GNN Design:** Develop a GNN architecture that incorporates both node and edge information. In Approach 1, the model infers edge features during training, while in Approach 2, predefined connectivity metrics are used. The GNN will be trained on the NMED-T dataset to classify EEG recordings into low, moderate, or high enjoyment levels.
5. **Training and Optimization:** Optimize the GNN through hyperparameter tuning and regularization techniques to enhance generalization and prevent overfitting.

This research aims to improve EEG-based cognitive state classification by leveraging both local brain activity and inter-channel relationships, ultimately leading to a more robust understanding of the brain's response to various stimuli.

Requirements:

- Proficiency in Machine Learning and Deep Learning techniques
- Strong skills in Python programming
- Familiarity with EEG data analysis is beneficial

Language: English



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